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Effect of seed treatments, spacing and season of sowing on yield and quality of coriander (*Coriandrum sativum* L.) under rain shelter

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Abstract

Coriander is an important herb & seed spice. The yield of coriander is influenced by the agronomic practices adopted during cultivation. This study was carried out in the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Kerala Agricultural University from July 2019 to March 2020 to analyse the effect of seed treatments, spacing and growing season on yield and quality of coriander leaves under rain shelter. The experiment was laid out in factorial completely randomized design (FCRD) with three replications. The study revealed that, presowing seed treatments improved the growth and yield of coriander than untreated seeds. The impact of seed treatments was conspicuous at the time of harvest on growth, yield and quality parameters. Hydropriming for 24 h was found to be the best presowing seed treatment followed by seed treatment with GA_3 50 ppm for 8 h. A closer spacing of 10 x 10 cm which accommodated more plants per unit area recorded the highest biomass and herbage yield plot^{-1}. October – December season was found to be the best for obtaining better growth and yield in leaf coriander. Hence, the study concluded that, hydropriming for 24 h or seed treatment with GA_3 50 ppm for 8 h, a closer spacing of 10 x 10 cm and October – December season are the ideal combination for the best performance of variety CO-4 for leaf purpose under rain shelter in the tropical moist humid climate.

Keywords: coriander, GA_3, growing season, hydropriming, NAA, rain shelter, seed treatments, spacing

Introduction

Coriander (*Coriandrum sativum* L) is one of the world's oldest spices whose use history can be traced back to 5000 BC. In many dishes the word is known for the dried seeds rather than to the whole plant and it is an un avoidable seed and herbal spice in all cuisines world over. Coriander is a member of carrot family Apiaceae or Umbelliferae and is indigenous to Southern Europe and Mediterranean region.

India is the largest producer of coriander seeds with 5, 83,000 ha area and 7, 84,000 MT of

annual production. It is mainly cultivated in Rajasthan, Madhya Pradesh, Andhra Pradesh, Gujarat, Tamil Nadu and Karnataka.

Coriander leaves display an impressive nutritional profile, as it is high in proteins and dietary fibres, with negligible cholesterol and saturated fats. Besides, they are a rich source of vitamins and minerals like vitamin A, vitamin C, vitamin E, zinc, calcium, magnesium, iron and phosphorus. Besides, the leaves also possess powerful antioxidants like carotenoids, flavonoids and anthocyanins which promote the anti-inflammatory and anti-microbial functions.

Though coriander can be cultivated throughout the year, the demand for coriander leaves is high during summer. Production as well as quality of the produce highly depends on the seasonal variations. Kerala is a high rainfall state with diverse agro climatic conditions. High rainfall and relative humidity result in biotic stresses which inhibit the growth of herbal spices like coriander. The concept of rain shelter, the naturally ventilated polyhouse will be ideal for the herbal spice production in Kerala.

Seed priming is a technique of presowing seed treatment with physical, chemical or biological substances to improve the growth and yield. Hydropriming and seed treatments with plant growth regulators enhance the germination, growth, yield and quality of many crops. Direct sowing of coriander also gives good germination percentage, but heterogeneous maturity of coriander seeds produce uneven and poor germination. The plant density is important to obtain maximum biomass yield of leafy vegetables. Optimizing the plant densities will not only improve the growth and yield but also reduce the input cost in terms of seed rate and fertilizers without reducing the yield and quality. The growing season is the period when crops grow successfully, exhibiting maximum growth and yield. Coriander can be grown for leaf purpose throughout the year but, the extreme variations in the climatic factors limit the growth and development during vegetative phase which lead to the incidence of pests and diseases as well as inferior quality. Hence, the present study was undertaken to evaluate the effect of seed treatments, spacing and growing season on growth, yield and quality of coriander variety CO-4.

Materials and methods

The field trial was carried out in rainshelter in the Plantation farm of Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during July 2019 to March 2020. The seeds of coriander variety CO-4, a dual purpose variety released from Tamil Nadu Agricultural University were collected from TNAU Coimbatore. There were two experiments conducted during two seasons *i.e*. July – September and October – December. Prior to the field preparation, lime was applied in the field at the rate of 600 kg ha^{-1}. Raised beds of 1 m^2 area were prepared. Basal dose of 5 t ha^{-1} FYM, 20:10:10 kg ha^{-1} NPK + 10 kg ha^{-1} N (top dressing) at 20 DAS were given.

Experiment No. 1. Standardization of seed treatments

The experiment consisted of five seed treatments including the control as given below.

$\mathbf{T_1}$: Splitting of seeds only

$\mathbf{T_2}$: Splitting of seeds and soaking in water for 12 h

$\mathbf{T_3}$: Splitting of seeds and soaking in water for 24 h

$\mathbf{T_4}$: Splitting of seeds and soaking in GA_3 50 ppm for 8 h

$\mathbf{T_5}$: Splitting of seeds and soaking in NAA 20 ppm for 8 h

Experiment No. 2. Standardization of spacing

The experiment was laid out with three row x plant spacings as given below.

$\mathbf{T_1}$: 30 x 10 cm (33 plants m^{-2})

$\mathbf{T_2}$: 20 x 10 cm (50 plants m^{-2})

$\mathbf{T_3}$: 10 x 10 cm (100 plants m^{-2})

Plant densities varied with the spacings.

Morphological and biochemical observations

The plants were harvested before the emergence of serrated leaves *i.e.*, at 40 days after sprouting. All growth, yield and quality parameters were recorded at the time of harvest. Ascorbic acid content of freshly harvested leaves was estimated by titration method (Rao & Deshpande 2005). The chlorophyll content was estimated by the Dimethyl Sulfoxide Method as per Hiscox & Isrealstam (1979). The essential oil present in the coriander leaves was extracted using Clevenger apparatus (Clevenger 1928).

Statistical analysis

The experiment was laid out in Factorial completely randomized design (FCRD) with three replications. The effect of different treatments was quantified, and the level of significance was determined by the analysis of variance (ANOVA) and least significant difference (LSD< 0.05) among mean values. Duncan's multiple range test was used to compare the treatment means.

Results and discussion

Seed treatments, spacing and season had significant influence on germination, growth, yield and quality of coriander variety CO-4.

Effect of seed treatments

Seed treatments had significant influence on sprouting as seen from data presented in Table 1. The seeds subjected to priming exhibited early sprouting than untreated seeds. Seeds hydroprimed for 24 hr and primed with GA_3 50 ppm and NAA 20 ppm for 8 hr recorded early germination. Priming might have improved the germination by accelerating imbibition which enhances the multiplication of radicle cells (Maroufi *et al*. 2011). The plant growth regulators such as GA_3 and NAA are widely used in agriculture for boosting the productivity. GA_3 induces the hydrolytic enzymes which triggers the weakness of seed coat by stimulating gene expression responsible for cell expansion and modification as reported in *Arabidopsis* by Finkelstein *et al*. (2008).

Different seed treatments had significant influence on growth characters like plant height and number of leaves (Table 1). Among the various treatments, the highest plant height (27.67 cm) and highest number of leaves per plant (8.77) were observed in GA_3 50 ppm treatment followed by NAA 20 ppm and hydropriming treatments. The magnitude of increase in plant height was more pronounced when the plants attained harvest maturity. Increase in plant height might be due to the stem elongation and cell division enhancement by GA_3. Gibberellin is a phytohormone that is responsible for regulation of plant height (Bano *et al*. 2016). GA_3 treatments are also effective for enhancing the vegetative growth by increasing the plasticity of the cell wall (Singh *et al*. 2012). The results obtained in the study are in line with the findings of Kumar *et al*. (2018); Haokip *et al*. (2016), Meena *et al.* (2006) and Verma (2002) in coriander. Application of NAA also enhanced the growth of coriander plants. It could be attributed to the improved photosynthetic ability of the plants (Haokip *et al*. 2016).

The yield parameters showed significant variation among the different seed treatments (Table 2). Hydropriming for 24 h was found to be the best seed treatment for yield attributing characters such as biomass yield $plot^{-1}$ and herbage yield $plot^{-1}$ followed by GA_3 at 50 ppm. The significant increase in biomass and green leaf yield might be due to the stimulation of

Table 1. Effect of seed treatments and season of sowing on growth parameters of coriander variety CO-4

Treatment /Season	Germination (days)			Plant height at harvest (cm)			Number of leaves at harvest		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	7.00	7.33	7.17^{a}	21.94	24.78	23.36^{d}	6.27^{c}	9.33^{b}	7.80^{b}
T_2	6.67	7.00	6.83^{ab}	22.78	25.25	24.02^{c}	6.33^{c}	9.40^{b}	7.87^{b}
T_3	6.33	6.33	6.33^{c}	23.07	25.97	24.52^{c}	6.40^{c}	9.60^{b}	8.00^{b}
T_4	6.33	6.33	6.33^{c}	26.32	29.01	27.67^{a}	6.67^{c}	10.87^{a}	8.77^{a}
T_5	6.33	6.33	6.33^{c}	24.49	27.68	26.08^{b}	6.53^{c}	10.53^{a}	8.53^{a}
Mean	6.53	6.67		23.72^{b}	26.54^{a}		6.44^{b}	9.94^{a}	
CD (Season)		NS			0.69			0.25	
CD (Treatments)		0.62			1.10			0.40	
CD (Season × Treatments)		NS			NS			0.57	

T_1: splitting of seeds only; T_2: splitting of seeds and soaking in water for 12 h; T_3: splitting of seeds and soaking in water for 24 h; T_4: splitting of seeds and soaking in GA_3 50 ppm for 8 h; T_5: splitting of seeds and soaking in NAA 20 ppm for 8 h; S_1: July – September; S_2: October - December

seedling emergence and early establishment of plants. Zarei *et al*. (2011) have reported the positive effects of hydropriming in chickpea and Ogbuehi *et al*. (2013) reported the influence of hydropriming on seed yield of groundnut.

The quality parameters also varied among the seed treatments (Table 3). Vitamin C content (65.54 mg $100g^{-1}$) was found to be highest when the seeds were treated with GA_3 50 ppm. Gibberellin also plays a vital role in sugar metabolism. The ascorbic acid is synthesized from the sugars and high vitamin C content might be due to the increased synthesis of sugars and due to the transformation of organic acids to sugars (Jangid *et al*. 2018). Active involvement of plant growth regulators leads to the breakdown of organic acids and sugars as suggested by Singh & Singh (2017). Increased vitamin C content with the application of GA_3 has also been reported by Kumar *et al*. (2012) in strawberry. Presowing

Table 2. Effect of seed treatments and season on yield parameters of coriander variety CO-4

Treatment/ Season	Biomass yield plot^{-1} (g m^{-2})			Green leaf yield plot^{-1} (g m^{-2})		
	S_1	S_2	Mean	S_1	S_2	Mean
T_1	65.20^{g}	333.63^{e}	199.42^{e}	58.50^{g}	317.17^{e}	187.83^{e}
T_2	81.57^{fg}	409.97^{c}	245.77^{c}	73.33^{fg}	393.83^{c}	233.58^{c}
T_3	95.73^{f}	527.87^{a}	311.80^{a}	83.67^{f}	513.00^{a}	298.33^{a}
T_4	94.13^{f}	453.67^{b}	273.90^{b}	80.33^{f}	434.33^{b}	257.58^{b}
T_5	71.43^{g}	367.63^{d}	219.53^{d}	59.67^{g}	349.67^{d}	204.67^{d}
Mean	81.61^{b}	418.55^{a}		71.20^{b}	401.60^{a}	
CD (Season)		9.65			6.93	
CD (Treatments)		15.26			10.96	
CD (Season × Treatments)		21.59			15.50	

T_1: splitting of seeds only; T_2: splitting of seeds and soaking in water for 12 h; T_3: splitting of seeds and soaking in water for 24 h; T_4: splitting of seeds and soaking in GA_3 50 ppm for 8 h; T_5: splitting of seeds and soaking in NAA 20 ppm for 8 h; S_1: July – September; S_2: October - December

Table 3. Effect of seed treatments and season on quality parameters of coriander variety CO-4

Treatment/ Season	Vitamin C content (mg 100g^{-1})			Volatile oil (%)			Total chlorophyll content (mg g^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	18.50^{f}	64.00^{c}	41.25^{c}	0.1	0.1	0.1	1.427^{f}	1.924^{c}	1.676^{d}
T_2	21.17^{f}	65.33^{c}	43.25^{c}	0.1	0.1	0.1	1.495^{e}	1.979^{b}	1.737^{c}
T_3	29.17^{e}	73.33^{b}	51.25^{b}	0.1	0.1	0.1	1.554^{d}	2.195^{a}	1.875^{a}
T_4	43.75^{d}	81.33^{a}	65.54^{a}	0.1	0.1	0.1	1.317^{g}	2.203^{a}	1.760^{c}
T_5	18.75^{f}	65.33^{c}	42.04^{c}	0.1	0.1	0.1	1.455^{ef}	2.178^{a}	1.817^{b}
Mean	26.27^{b}	69.87^{a}		0.1	0.1		1.450^{b}	2.096^{a}	
CD (Season)		1.44			NS			0.025	
CD (Treatments)		2.28			NS			0.039	
CD (Season × Treatments)		3.23			NS			0.056	

T_1: splitting of seeds only; T_2: splitting of seeds and soaking in water for 12 h; T_3: splitting of seeds and soaking in water for 24 h; T_4: splitting of seeds and soaking in GA_3 50 ppm for 8 h; T_5: splitting of seeds and soaking in NAA 20 ppm for 8 h; S_1: July – September; S_2: October - December

seed treatment had significant effect on total chlorophyll content also. Hydropriming for 24 h recorded highest total chlorophyll content (1.875 mg g^{-1}) in fresh leaves. Mohajeri *et al*. (2017) reported that presowing seed treatment with water for 12 hours recorded highest total chlorophyll content in *Phaseolus vulgaris*. Similarly, hydropriming for different durations significantly increased the chlorophyll 'b' content of *Moringa oleifera* leaves (Nouman *et al*. 2012). The essential oil content was found to be unaffected by various seeds treatments.

Effect of spacing

Data presented in Table 4 revealed non significant effect of spacing on sprouting of seeds whereas, spacing markedly influenced plant height and number of leaves. Among the three row spacings, closer spacing of 10 x 10 cm recorded significantly highest plant height (25.02 cm) and number of leaves (9.10) at harvest followed by medium spacing of 20 x 10 cm (23.83 cm and 9.00 respectively). Plant might have adjusted its canopy in the vertical space

Table 4. Effect of spacing and season on growth parameters of coriander variety CO-4

Treatment/ Season	Germination (days)			Plant height (cm)			Number of leaves		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	7.33	6.00	6.67	20.65	23.39	22.02^{c}	5.93^{c}	9.53^{b}	7.73^{b}
T_2	7.33	6.33	6.83	19.65	28.01	23.83^{b}	6.33^{c}	11.67^{a}	9.00^{a}
T_3	7.00	6.33	6.67	21.37	28.67	25.02^{a}	6.40^{c}	11.80^{a}	9.10^{a}
Mean	7.22	6.22^{a}		20.56^{b}	26.68^{a}		6.22^{b}	11.00^{a}	
CD (Season)		0.49			0.58			0.47	
CD (Treatments)		NS			0.71			0.58	
CD (Season × Treatments)		NS			1.00			0.82	

T_1: 30 x 10 cm; T_2: 20 x 10 cm; T3: 10 x 10 cm; S_1: July – September; S_2: October - December

Table 5. Effect of spacing and season of sowing on yield parameters of coriander variety CO-4

Treatment/ Season	Biomass yield plot^{-1} (g m^{-2})			Green leaf yield plot^{-1} (g m^{-2})		
	S_1	S_2	Mean	S_1	S_2	Mean
T_1	63.47^{e}	244.51^{c}	153.99^{c}	56.54^{e}	230.78^{c}	143.66^{c}
T_2	138.57^{d}	642.10^{b}	390.33^{b}	129.50^{d}	626.17^{b}	377.83^{b}
T_3	235.67^{c}	1131.20^{a}	683.43^{a}	217.33^{c}	1088.67^{a}	653.00^{a}
Mean	145.90^{b}	672.60^{a}		134.45^{b}	648.54^{a}	
CD (Season)		24.07			23.39	
CD (Treatments)		29.48			28.65	
CD (Season × Treatments)		41.69			40.52	

T_1: 30 x 10 cm; T_2: 20 x 10 cm; T3: 10 x 10 cm; S_1: July – September; S_2: October - December

by increasing inter nodal length under closer spacing. These results are in accordance with the findings of Amaglo *et al*. (2007) in *Moringa oleifera* leaves, Farooq (2013) in coriander and Venugopal (2006) in patchouli.

The effect of row spacing on biomass and herbage yield plot^{-1} was highly significant. The highest biomass and herbage yield plot^{-1} were realised in the spacing of 10 x 10 cm. As the row spacing decreased from 30 cm to 10 cm, biomass yield plot^{-1} increased from 153.99 g m^{-2} to 683.43 g m^{-2}. Similarly, the herbage yield plot^{-1} increased from 143.66 g m^{-2} to 653.00 g m^{-2}. The number of plants increased with the decrease in row spacing and highest number of plants could be accommodated in closer spacing of 10 x 10 cm. Similar results were also recorded by Kaur (2019) in coriander and Asundi (2001) in Japanese mint.

Spacing had significant effect on the Vitamin C content of fresh leaves. The Vitamin C content varied from 45.29 mg 100 g^{-1} to 65.16 mg 100 g^{-1}, irrespective of season. Highest Vitamin C content was recorded in closer (65.16 mg 100 g^{-1}) as well as medium (64.62 mg 100 g^{-1}) spacings. It could be due to the increased leaf temperature in wider spaced plants. Mahendran and Bandara (2000) reported the decrease in Vitamin C content of chilli fruit (*Capsicum annuum* L.) due to high leaf temperature.

Table 6. Effect of spacing on quality parameters of coriander variety CO-4

Treatment/ Season	Vitamin C content (mg 100 g^{-1})			Volatile oil content (%)			Total chlorophyll (mg g^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	29.26^{f}	61.33^{c}	45.29^{b}	0.1	0.1	0.1	1.223^{e}	2.169^{c}	1.696^{b}
T_2	43.90^{e}	85.33^{a}	64.62^{a}	0.1	0.1	0.1	1.326^{d}	2.447^{a}	1.887^{a}
T_3	54.32^{d}	76.33^{b}	65.16^{a}	0.1	0.1	0.1	0.957^{f}	2.183$_{b}$	1.570^{c}
Mean	42.49^{b}	74.22^{a}		0.1	0.1		1.169^{b}	2.266^{a}	
CD (Season)		1.31			NS			0.007	
CD (Treatments)		1.60			NS			0.009	
CD (Season × Treatments)		2.26			NS			0.013	

T_1: 30 x 10 cm; T_2: 20 x 10 cm; T3: 10 x 10 cm; S_1: July – September; S_2: October - December

Spacing did not influence essential oil content in the leaves. This might be due to the negligible quantity of essential oil in coriander leaves compared to seeds. The total chlorophyll content was highest under medium spacing of 20 x10 cm followed by 30 x 10 cm. This could be due to the light effect, more light will be intercepted by wider spaced plants which could have helped in profuse vegetative growth and more synthesis of chlorophyll.

Effect of growing season

The growth, yield and quality parameters of coriander variety CO-4 varied between the seasons, irrespective of seed treatment and spacing. The growth parameters such as plant height and number of leaves plant^{-1} were found to be highest during October – December. This increase in growth parameters were reflected in the yield parameters such as biomass and herbage yield plot^{-1} at the time of harvest (Fig. 1). There was 4.79 and 5.10 fold increase in biomass and herbage yield plot^{-1} respectively during October – December compared to July - September. Growing season plays an important role in all seed spices including coriander and there are reports indicating off season cultivation negatively affect the quantity and quality of coriander. Findings of the present study are also in line with the observations of Mohanalakshmi *et al*. (2019), Singh *et al*. (2000), and Meena *et al*. (2006) in coriander. The quality parameters also varied between the two growing seasons. Highest vitamin C content (Fig. 2) and highest total chlorophyll content in the leaf were recorded in the October – December crop. The vitamin C content increased by 109.54 per cent during October – December. The better growth parameters observed in the October – December season might have influenced the production of more metabolic compounds in coriander leaves leading to higher quality. Total rainfall received, number of rainy days and the relative humidity were lower during October – December when compared to July – September season. On the other hand, the total sunshine hours recorded was more during October – December. Favourable effect of these weather parameters also might have contributed to the better growth and yield of coriander during this season. The October – December season, where the quantum of light is more might have added to the improved Vitamin C content in leaves. Similar opinion was also given by Mohanalakshmi *et al*. (2019). Oyama *et al.* (1999) reported that ascorbic acid concentration increases with increased exposure to light, particularly in leafy greens such as spinach. The essential oil content did not vary with the seasons. This might be due to the negligible quantity of essential oil present in the coriander leaves as observed by Mohanalakshmi *et al*. (2019).

Interaction effect

The interaction effect of two factors *i.e.*, seed treatment and spacing with the season of growing was also worked out from the data.

Seed treatment x season

The interaction effect of seed treatments and season on yield was found to be significant. Highest biomass and herbage yield plant^{-1} was recorded in a combination of hydropriming for 24 h and October – December season. Highest vitamin C content was recorded in a combination of GA_3 50 ppm and October – December season.

Spacing x season

The interaction effect of spacing and season too was significant with respect to biomass and herbage yield plot^{-1}. Highest biomass and herbage yield^{-1} were obtained when plants were grown in closer spacing of 10 x 10 cm during October – December. Vitamin C content was highest in medium spacing during the same season.

In conclusion, the present study revealed that, rain shelter cultivation of coriander during October – December is ideal under tropical moist humid conditions for obtaining

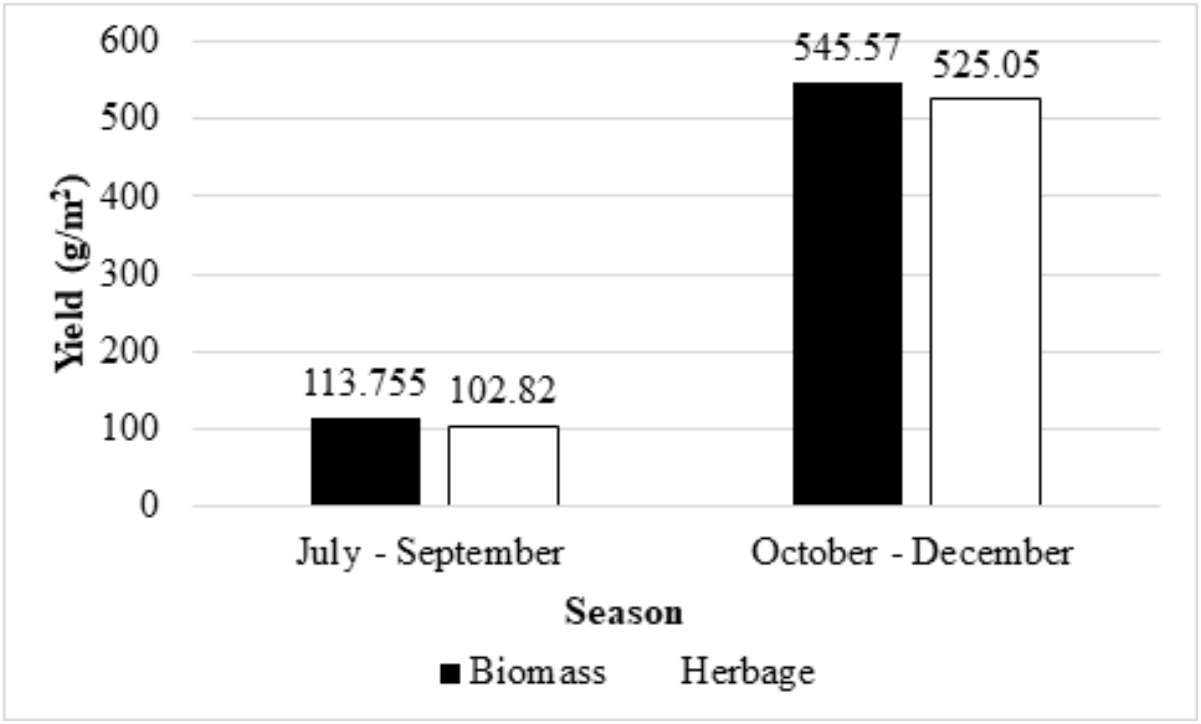

Fig.1. Effect of growing season on yield parameters of coriander variety CO-4

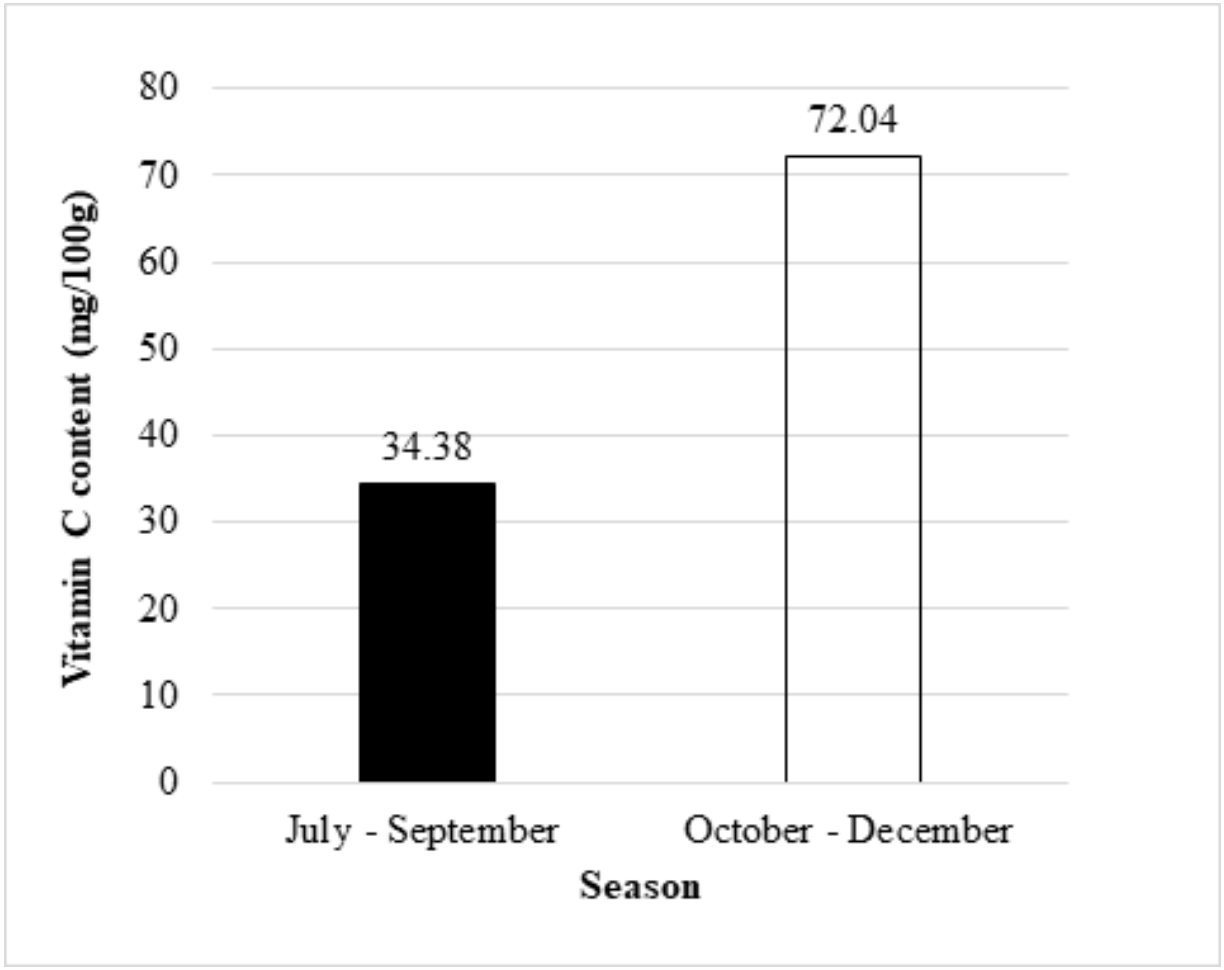

Fig.2. Effect of growing season on vitamin C content of coriander variety CO-4

maximum herbage yield. Hydropriming for 24 hours and GA_3 50 ppm for 8 hours can be used as presowing seed treatments for increasing the growth and yield. A closer spacing of 10 x 10 cm is ideal for obtaining maximum biomass and herbage yield from an unit area.

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